arXiv:astro-ph/0201068v2 16 Apr 2002

Do Young Neutron Stars Which Show Themselves As AXPs, SGRs and Radio Pulsars Accrete?

S. O. TAGIEVA[1] *, E. YAZGAN[2] †, and A. ANKAY[2] ‡

[1]Academy of Science, Physics Institute Baku 370143, Azerbaijan Republic
[2]Middle East Technical University, Department of Physics, Ankara, Turkey

Abstract

We examined the fall-back disk models, and in general accretion, proposed to explain the properties of anomalous X-ray pulsars (AXPs), soft gamma repeaters (SGRs), and radio pulsars (PSRs). We checked the possibility of some gas remaining around the neutron star after the supernova explosion. We also compared AXPs and SGRs with the X-ray pulsars in X-ray binaries. We conclude the existing models of accretion from a fall-back disk are insufficient to explain the nature of AXPs/SGRs, particularly the SGR bursts. We also discussed the proposed model of combination of magnetic dipole radiation and propeller torques in order to explain the evolution of radio pulsars on the P-$\dot{P}$ diagram. We found that the predictions of this model contradict the observational data.

KEY WORDS AXP, SGR, PSR, SN

*e-mail:msalima@lan.ab.az
†e-mail:yazgan@astroa.physics.metu.edu.tr
‡e-mail:askin@astroa.physics.metu.edu.tr

1 Introduction

In the last few years soft gamma ray repeaters (SGRs) and anomalous X-ray pulsars (AXPs), which are considered as a separate class of X-ray pulsars, have attracted much attention (see Mereghetti 2001 and references therein). The only important difference between SGRs and AXPs is that SGRs have active periods showing gamma ray bursts. A puzzling property of these objects is that their X-ray luminosities (L_x) are 1-3 orders of magnitude higher than their rate of rotational energy loss ($\dot{E}$). Besides, repeating gamma ray bursts of SGRs is the most important property of this class of objects. In order to explain the main physical peculiarities of these objects, not only a theory overstepping the limits of the standard NS/pulsar physics is needed, but also examining another type of NS, known as radio quiet NS, with low X-ray luminosity is required.

There is no radio radiation observed from AXPs/SGRs, only the upper limits for radio fluxes (and luminosities) are known (Gaensler et al. 2001). It does not necessarily mean that these objects do not radiate in the radio band only because of failing to observe radio pulses, because most of the pulsars are born with low luminosities (Lyne et al. 1998; Allahverdiev et al. 1997) and also because of the beaming factor. However, if somehow it is shown that AXPs and SGRs do not radiate in the radio band, then there will be a sharp drop in the radio luminosity of pulsars including AXPs and SGRs as we go to higher magnetic fields. It is difficult to check this possibility because it is not easy to increase the number of such observational data as the number of AXPs and SGRs are small and they are located at large distances.

The so called magnetar model is proposed by Thompson and Duncan (1995) as a potential explanation for the nature of AXPs and SGRs. According to this model these sources are isolated rotating NSs with surface dipole magnetic fields of 10^{14}-10^{15} G, extracting their luminosity from the decay of the magnetic field.

The alternative model is that the X-ray luminosity is due to accretion from a fall-back disk that is left over from the supernova that formed the NS (Chatterjee et al. 2000; Alpar 2001). In this work we will show the incompetence of the *existing* accretion models in explaining the AXPs, SGRs, and also radio pulsar properties. In section 2, the similarities and differences between SGR bursts and flares of flare stars are shown qualitatively and quantitatively. In section 3, we investigated the possibility of a fossil disk remaining around the NS after the SN explosion, and if such a disk exists,

the effects of this disk on the observed properties of the NS. In section 4, we compared the specific angular momentum transfer in AXPs and SGRs with the specific angular momentum transfer in X-ray binaries. In section 5, after a brief review of history of accretion theory, we showed that the proposed propeller mechanism for radio pulsars can not account for the evolution of radio pulsars on the P-$\dot{P}$ diagram. The *existing* fall-back disk models proposed to explain the nature of AXPs and SGRs are not well developed that some predictions of these models contradict some of the observational data. These will be shown below.

2 Bursts and Flares Due to Magnetic Activities

In general bursts, and in particular gamma-ray bursts, are common astronomical phenomena. In this section we compare SGR bursts with the bursts of well known objects in astrophysics. Bursts are observed, for instance, for the Sun, flare stars (UV-Cet type), and T-Tauri stars. Flares have fast rise-times of luminosity and longer decay times. For all of the flaring objects, the flares are related to the magnetic activities and have short characteristic times ($\sim$minutes for UV-Cet stars). Intense flares are followed by less-intensive ones. Durations of SGR bursts (10 ms-10 s) bear resemblance to (taking into account the very small size of the NS) the durations of flares; roughly, duration of a flare is directly proportional to the size of the star. Flares occur on a large portion of the surface of flare stars. This must be also true for SGRs since the bursts, particularly the giant bursts, can not be produced on a small portion of the neutron star's surface. Radius of a typical UV-Cet type star is about $R_{flare}=10^{10}$ cm, and of a neutron star is about $R_{NS}=10^6$ cm. Taking typical flare duration (Δt_{flare}) to be 1 minute, the duration of the SGR burst can be estimated to be 60 ms. This value is consistent with the observed Δt_{SGR} values. The difference between flares and SGR bursts is the power output, and time intervals between the strong flares (for UV Cet stars it is, on the average, about 10-100 times shorter compared to SGR bursts). The ratio of the energy of outburst to the persistent radiation energy for flare stars (UV-Cet type) can be as large as 10^4 and for SGRs 10^8. Since AXPs and SGRs are considered as one class of objects, we must enquire if AXPs also have outbursts, however, not frequently and/or with low intensity.

SGR bursts have very large energies in the range $\simeq 10^{40-44}$ erg with characteristic timescales of 10 ms-10 s. Such bursts can not be brought

into existence by the *existing* accretion (onto a NS) models and such bursts have never been observed in accreting binary systems even though X-ray luminosities of some binaries are about two orders of magnitude higher than the persistent X-ray radiation of AXPs and SGRs. It must be noted that, the X-ray bursts in low mass X-ray binaries (LMXBs) are due to accretion powered thermonuclear reactions on the surfaces of old NSs (Lipunov 1992). For these bursts to occur the magnetic field of the burster should be small. The burster characteristic has not been observed for high mass X-ray binaries (HMXBs). For transient X-ray binaries the bursts are due to change in the accretion rate. The source of these bursts observed from transients and bursters, which have very different physical mechanisms, is not the magnetic field of the NS, but accretion. Moreover, the spectra of the bursts observed from X-ray binaries and SGRs are different.

As we see above, characteristics of the SGR bursts are similar to the characteristics of flares. This is an evidence that the origin of SGR bursts is the magnetic field of the NS. If this is the case, magnetic field of the NS must be $\sim 10^{14}$-10^{15} G to power the SGR bursts with energies of $\sim 10^{40}$-10^{44} erg (Thompson & Duncan 1995). The *existing* accretion models avoid to explain the SGR bursts and this is the most important handicap of such models.

3 The Fall-Back Disk Model

3.1 Can a Disk Remain Around a Neutron Star After Supernova Explosion?

The X-ray luminosity (L_x) of AXPs and SGRs can be explained by accretion, however, the compactness of the values of L_x is achieved due to the fact that the parameters $\dot{M}$ and B are adjustable in a wide range in the accretion models.

In the fall-back disk models, it is very important to know how much mass of gas may remain close to the NS after the supernova explosion. Gravitational energy of a NS with one $M_\odot$ and a radius about 1.5×10^6 cm can be estimated as (1-2)$\times10^{53}$ ergs which is about 5-10% of $M_\odot c^2$. The gravitational energy is converted into heat and rotational energy, and this heating energy, about 10^{53} ergs, transforms into the energy of neutrinos and antineutrinos during supernova explosion (Zeldovich and Guseinov 1965, Guseinov 1966). From the study of SNRs, it is known that their kinetic energies lie in the interval $\sim 3\times10^{49} - 10^{51}$ ergs. From the observations

of SNe it is known that the explosion energy, on the average, lies in the interval 10^{50}-10^{51} ergs and the thrown out mass of gas is $\sim$(0.5-4)$M_\odot$. This shows that only a small part of the energy of the neutrinos transform into explosion energy, but, in principle, this is enough to sweep out all the mass which are present near the NS. On the other hand, whether some fall-back matter remain near the NS (and also its quantity) depends on the velocity distribution of the thrown out matter.

The part of the gravitational energy which is transformed into rotational energy of the NS mainly depends on initial value of angular momentum (and its distribution) of the collapsed star. Even if we know these values, in order to calculate the rotational energy of the NS we must also know the value of the magnetic viscosity as well as the dynamics of the collapse and the explosion. At this point, there are many uncertainties and therefore angular momentum and rotational energy of the NS should be estimated from the initial period of pulsars. Since, the initial period is about 10 ms, initial rotational energy of the NS must be about 5×10^{51} ergs. The collapse transforms the angular momentum from the NS (which is about to be born) to external parts and this can sweep out the surrounding matter (Bisnovatyi-Kogan 1971; Amnuel et al. 1973). Actually, observational data do not show presence of gaseous disks or planets near single pulsars with a magnetic field in excess of 10^{10} G. Optical observations given in Kaplan et al. (2001) showed that there is no optical counterpart of SGR 0526-66 and no accretion disk is present around the NS. Moreover, due to precession of the disc around the NS and/or inhomogeneities in the disc, variations in the dispersion measure values of PSRs must have been observed at least for some of the nearby young PSRs. Therefore, there is no basis for the presence of any matter of fall-back around AXPs and SGRs, but we can not completely exclude the possibility of a little bit of gas, which can not be observed, remaining near the neutron star.

3.2 Are AXPs and SGRs Accreting Systems?

As we indicated above, an unobservable amount of matter might remain around the NS. Below, we examine if such a small amount of matter spins up or spins down the NS. When the collapse begins to slow down, the SN explosion occurs and the shell around the NS is thrown away. Due to conservation of angular momentum, the rotational speed of the shell will decrease as it moves away from the NS. At the beginning, the magnetic field of the NS is frozen to the shell. This slows down the NS, and speeds up the shell

(Bisnovatyi-Kogan 1971 and Amnuel et al. 1973). Angular speed of the shell falling back increases. Consequently, the NS will be spun-up by the fall-back matter if the propeller mechanism is not working simultaneously, i.e. if the fall-back matter does not lose angular momentum. However, the *existing* accretion from a fall-back disk models do not explain how the fall-back disk loses angular momentum instead of gaining it. Models based on fall-back disk should include propeller mechanism as well as accretion mechanism working together simultaneously.

In the *existing* fall-back disk models the parameters of the disk (related to the magnetic field and rotational speed of NS) is chosen such that the X-ray luminosity is about 10^{34-36} erg/s and $\dot{\mathrm{P}} \approx 10^{-13} - 10^{-11}$ s/s. So, the *existing* models, in fact, are not related to the properties and history of the fall-back matter. On the other hand, the only accretion model (onto a 10^{12} G NS) which takes into account the small ages of AXPs and SGRs is the model of accretion from a fall-back disk.

4 Comparisons Between AXPs/SGRs and X-ray Pulsars in Binaries

We examined the differences between $\mathrm{L}_x/|\dot{\mathrm{E}}|$ values of AXPs, SGRs, and X-ray pulsars in binary systems. Here, L_x is the X-ray luminosity which depends only on the rate of accreted mass, $\dot{\mathrm{M}}_x$, and $\dot{\mathrm{E}}$ is the rate of rotational energy change which depends on both $\dot{\mathrm{M}}_x$ and specific angular momentum, L_{spc}. Therefore, $\mathrm{L}_x/|\dot{\mathrm{E}}|$ will be inversely proportional to L_{spc}. In Table 1, L_x and $|\dot{\mathrm{E}}|$ values (and their ratio) of X-ray pulsars in high mass X-ray binaries (HMXBs), a LMXB, and AXPs/SGRs with known $\dot{\mathrm{P}}$ values are displayed (we do not include transient X-ray binaries in this table, because it is difficult to determine the correct value of $\mathrm{L}_x/|\dot{\mathrm{E}}|$ for such systems). For HMXBs, $\mathrm{L}_x/|\dot{\mathrm{E}}|$ values range from 3×10^3 to 3×10^6, with one exception, namely H0115-737, which has a lower $\mathrm{L}_x/|\dot{\mathrm{E}}|$ value of 65. This is because of the small spin period value of this pulsar. There is only 1 LMXB with reliable $\dot{\mathrm{P}}$ and L_x values and its $\mathrm{L}_x/|\dot{\mathrm{E}}|$ value is (5-7.5)$\times 10^2$, less than all of the $\mathrm{L}_x/|\dot{\mathrm{E}}|$ values of HMXBs which have spin periods close to spin periods of AXPs and SGRs.

Accretion onto a NS can spin it up or down. However, for binary systems with the same parameters, we expect that as $\dot{\mathrm{M}}_x$ increases $\dot{\mathrm{P}}$, $|\dot{\mathrm{E}}|$ and L_x increase. There is disk accretion in LMXBs and unit mass of the accreted matter has more angular momentum compared to the unit mass of

the accreted matter in HMXBs since, on the average, they have higher orbital velocity. Because of this reason, for LMXBs $L_x/|\dot{E}|$ is smaller than for HMXBs, on the average. Without the propeller effect, value of $L_x/|\dot{E}|$ for fall-back matter accreted onto the NS must not be smaller than for X-ray pulsars in HMXBs if their spin period values are close to each other. As seen from Table 1, 4 of 7 AXPs/SGRs seem to have lower values than LMXBs that accretion from fall-back matter without propeller effect contradicts the observational data. On the other hand, the propeller effect must be weak enough not to be observed in the plerionic parts of the SNRs, because the SNRs which have genetic connections with AXPs have pure shell type structures (Gaensler et al. 2001; Tagieva & Ankay 2002).

5 The Other Aspects of Accretion: Single Stars

Classical accretion (onto a single star) theory is a very developed and well known subject in astrophysics. To explain the radiation from stars, in early times, accretion from interstellar medium and contraction of stars were proposed. Later it was understood that thermonuclear reactions in the cores of stars are the source of radiation of stars, then there was no need for accretion anymore. On the contrary, it was found that stars have winds, sometimes very strong winds.

Salpeter (1964) tried to explain the X-ray sources (when they were first found by Giacconi et al. 1962) based on accretion from interstellar medium onto a single neutron star. So, accretion onto single stars was called to mind. It is well-developed for systems including NSs and black holes. However, accretion from interstellar medium is found to be wrong, because it is found that if there is accretion onto a single NS, then the NS becomes hotter and the speed of sound in the surrounding matter increases, so that the accretion rate decreases by 6 (Schwartsman 1970) or 8 (if the magnetic field frozen in the interstellar medium is also taken into account, Amnuel and Guseinov 1972) orders of magnitude. X-ray sources were explained as accreting binary sytems (Zeldovich and Guseinov 1966).

After PSRs were discovered, it was understood that rapidly rotating single NSs also produce winds (Pacini 1967). Such winds are much more efficient than radiation pressure in sweeping out the surrounding matter around PSRs (Lipunov 1992). Then accretion theory could only work for slowly rotating single NSs with low magnetic fields. For 30 years, this has been searched for accreting old single NSs in optical and soft X-ray

bands without considerable success (Danner 1998). Also there was no success in finding fluctuating (accreting from interstellar medium) single black holes (Schwartsman 1970). Moreover, there is no sign of fall-back matter in the central parts, particularly in the near-environments, of point sources of historical (i.e. very young) SNRs Crab (PSR J0534+2200), 3C58 (RX J0201.8+6435, Torii et al. 2000; Bocchino et al. 2001), Cas A (CXO J2323+5848, McLaughlin et al. 2000; Kaplan et .al 2001).

5.1 Propeller Mechanism for Radio Pulsars

Despite the facts against accretion onto single NSs given above, Alpar et al. (2001) following Menou et al. (2001) have proposed that the distribution of radio pulsars in P-$\dot{\mathrm{P}}$ diagram can be explained by the combination of magnetic dipole torque and propeller torque of a fall-back disk, instead of pure magnetic dipole radiation torque. Alpar et al. (2001) predicted the evolutionary tracks (represented with the 2 curves in Figure 1) of pulsars on the P-$\dot{\mathrm{P}}$ diagram. Constant B-field lines are also shown in Figure 1 to make a comparison between them. According to Peng et al. (1982) and Huang et al. (1982) neutrino emission from pulsars and magnetic dipole radiation of superfluid neutrons, respectively, also yield tracks similar to those of Alpar et al. (2001). As seen in Figure 1, down to a minimum period derivative value, pulsars follow dipole-dominant radiation tracks and after that point pure dipole and combined dipole+propeller tracks diverge from each other. Period derivative becomes $\dot{\mathrm{P}} \propto P^3$ in the propeller-dominant phase. This diversion also reflects that, after the dipole-dominant phase is over, the ages predicted by the model of Alpar et al. (2001) and the characteristic ages (which are determined by the effect of pure magnetic dipole radiation torque) follow different paths as can be seen in Figure 1.

The real ages of pulsars are the kinetic ages which are valid for all models; the kinetic age is proportional to the distance of the PSR from the Galactic plane (see e.g. Lyne & Graham-Smith 1998). So, the dipole+propeller model can be tested by comparing the model's age predictions with the kinetic ages. According to the dipole+propeller model, older pulsars must be located in the upper right part of the P-$\dot{\mathrm{P}}$ diagram, and these pulsars must be far away from the Galactic plane, i.e. their kinetic ages must be larger. In order to check this, we constructed the P-$\dot{\mathrm{P}}$ diagram by representing the pulsars with $|z| < 200$ pc with + symbol and the pulsars with $|z| > 400$ pc by open circles in Figure 1, where $|z|$ is the distance of pulsar from the Galactic plane.

In general, the birth places of pulsars are very close to the Galactic

plane. The average scale height at the time of birth is about 60 pc, similar to OB stars' average scale height. However, in the outer parts of the Galaxy, the star formation regions might deviate from the geometric plane of the Galaxy. Optical observations of cepheids with high luminosities and of red supergiants located at distances about 5-10 kpc from the Sun, in the directions l$\sim 200^o - 330^o$, showed that the star formation regions are located below the Galactic plane by about 300pc, and the star formation regions in the directions l$\sim 70^o - 100^o$ are located above the plane by about 400pc. The star formation regions at about 3-5 kpc from the Sun in the directions l$\sim 270^o - 320^0$ are located about 150 pc below the geometric plane of the Galaxy (Berdnikov 1987). These deviations of the locations of star formation regions from the Galactic plane have strong influence on the kinetic ages of young pulsars. We did not include the pulsars located in the deviated parts of the star formation regions indicated above. We also did not include the pulsars beyond 5 kpc due to large uncertainties in the distance measurements. As seen from Figure 1, along the path (from left to right) of the dipole+propeller tracks, kinetic ages first increase and then start to decrease. This is inconsistent with the propeller model. Therefore, dipole+propeller model can not account for the evolution of pulsars on the P-$\dot{\mathrm{P}}$ diagram. Age predictions due to pure magnetic dipole radiation mechanism are in good agreement with the kinetic ages (see Figure 1). Also, Allakhverdiev & Tagieva (2002) showed that magnetic dipole evolutionary tracks are more reliable; pulsars evolve roughly with constant magnetic field, number of pulsars increase with characteristic time on constant magnetic field lines.

Only a few of the pulsars with characteristic ages less than 10^6 years are more than 400pc away from the plane (see Figure 1) which could be related to their place of birth being high above the Galactic plane (the progenitor can be a runaway star) and their speed being large.

There is also another possibility to test the propeller model of Alpar et al. (2001) which predicts the change of $\dot{\mathrm{P}}$ ($\ddot{\mathrm{P}}$) to be the highest on the propeller-dominant parts of the evolutionary tracks. In order to find the braking index (n=$\ddot{\Omega}\Omega/\dot{\Omega}^2$, where Ω is the angular frequency of the pulsar) the value of $\ddot{\mathrm{P}}$ must be large. About 40 years of observations have shown that, in that part of the diagram, $\ddot{\mathrm{P}}$ values of pulsars are not large enough to be measured. This also contradicts the propeller model.

Glitch is a common phenomenon for young radio pulsars. According to the model of Alpar et al. (2001) for pulsars with P$>$ 1 s and $\dot{\mathrm{P}}> 10^{-14}$ s/s no glitch must be observed, because according to their model these pulsars

must be older than about 10^7 yrs. If glitches from these pulsars are observed, then this will directly show that they are young.

6 Conclusions

In this work, we have focused on if a residual (fossil) disk may remain around single NSs (AXPs, SGRs, and radio pulsars) after the supernova explosion and the effects of such a disk on the NS properties. We approached the problem from various different ways. We tried to clarify the physical nature of these objects and the existing accretion models in the light of observational data. In summary, we have showed that:
1) The characteristics of SGR bursts are similar to the characteristics of flares of flare stars all of which have the same source (origin): the magnetic field of the star, but not accretion onto the star.
2) After the supernova explosion, only a little amount of mass may remain around a single NS. The explosion energy of the thrown out matter is enough to sweep out most of the mass around the NS.
3) The surrounding matter can also be swept out by angular momentum transfer due to magnetic braking and this is supported by observational data which do not show gaseous disks or planets (or the effects of these) near single pulsars with a magnetic field in excess of 10^{10} Gauss.
4) Even if such a little amount of mass remains around the NS, it spins up the NS (instead of spinning it down) unless the propeller mechanism is working together with accretion simultaneously. We showed this also by $L_x/\dot{E}$ considerations in section 4. However, the propeller effect should be weak enough not to be observed since all the AXPs genetically connected to SNRs are pure shell type remnants. Fall-back disk models should be constructed taking these facts into account.
5) Comparing the kinetic ages of pulsars with the age predictions of the propeller+dipole model for radio pulsars, we showed that there is a strong contradiction between them. So, propeller model does not work for radio pulsars.

Acknowledgments. It is a pleasure to thank Oktay H. Guseinov for fruitful and stimulating discussions. We thank Gennadi S. Bisnovatyi-Kogan for comments on the manuscript. We also thank TÜBİTAK, the Scientific and Technical Research Council of Turkey, for support through TBAG-ÇG4.

References

Allakhverdiyev, A.O., Guseinov, O.H. & Tagieva, S.O., 1997, Astronomy Letters, 23, 628

Allakhverdiev, A. O. & Tagieva, S. O., 2002, will be published in Astronomical and Astrophysical Transactions

Alpar, M.A., 2001, ApJ, 554, 1245

Alpar, M.A., Ankay, A. & Yazgan, E., 2001, ApJL, 557, 61

Amnuel, P. R. & Guseinov, O. H., 1972, Astron. Nach. Bd. 294, 139

Amnuel, P.R., Guseinov, O.H., & Kasumov, F.K., 1973, Sov. Ast., 16, 932

Angelini L., White, N. E., Nagase, F., et al., 1995, ApJ, 449, L41

Baykal, A. & Swank, J., 1996, ApJ, 460, 470

Bisnovatyi-Kogan, G., 1971, Sov. Ast. 14, 652

Berdnikov, L.N., 1987, Pisma v Astron. Journal, 13, 110

Bonnet-Bidaud, J. M. & van der Klis, M., 1981, A&A, 97, 134

Burderi, L., di Salvo, T., Robba, N. R., del Sordo, S., Santangelo, A., Segreto, A., 1998, ApJ, 498, 831

Burderi, L., Di Salvo, T., Robba, N. R., La Barbera, A., Guainazzi, M., 2000, ApJ, 530, 429

Chakrabarty, D., Bildsten, L., Grunsfeld, J. M., et al., 1997, ApJ, 474, 414

Chatterjee, P., Hernquist, L., & Narayan, R., 2000, ApJ, 534, 373

Clark, G. W., 2000, ApJ, 542, L131

Clark, G. W., Woo, J. W. & Nagase, F., 1994, ApJ, 422, 336

Corbet, R. H. D. & Mihara, T., 1997, ApJ, 475, L127

Danner, R., 1998, AAS, 128, 349

Fahlman, G. G. & Gregory, P. C., 1981, Nature, 293, 202

Gaensler, B.M., Slane, P.D., Gotthelf, E.V. & Vasisht, G., 2001, ApJ, 559, 963

Giacconi, R., Gursky, H., Paolini, F. & Rossi, B., 1963, Phys. Rev. Lett., 9, 439

Gotthelf, E. V., Vasisht, G. & Dotani, T., 1999, ApJ, 522, L49

Guseinov, O.H., 1967, AJ., 43, 772, 1967, Sov. Ast., 10, 613

Haberl, F., Dennerl, K., Pietsch, W. 1995, A&A 302, L1

Hanson, C. G., Skinner, G. K., Eyles, C. J. & Willmore, A. P., 1989, MNRAS, 240, L1

Huang, J., -H., Lingenfelter, R. E., Peng, Q., -H. and Huang, K., -L.,

1982, A&A, 113, 9
Hulleman, F., van Kerkwijk, M. H. & Kulkarni, S. R., 2000, Nature, 408, 689
Hutchings, J. B., Cowley, A. P., Crampton, D., et al., 1974, ApJ, 191, L101
Israel, G. L., Mereghetti, S. & Stella, L., 1994, ApJ, 433, L25
Israel, G. L., Covino, S., Stella, L., et al., 1999a, ApJ, 518, L107
Israel, G. L., Oosterbroek, T., Angelini, L., et al., 1999b, A&A, 346, 929
Kaplan, D.L., Kulkarni, S.R., van Kerkwijk, M.H., et al., 2001, ApJ, 556, 399
Kaspi, V. M., Chakrabarty, D. & Steinberger, J., 1999, ApJ, 525, L33
Kaspi, V. M., 2000, Pulsar Astronomy 2000 and Beyond, ASP Conference Series, edited by M. Kramer, N. Wex & R. Wielebinsky, vol. 202, p.485, astro-ph/9912284
Kelley, R. L., Rappaport, S., Clark, G. W. & Petro, L. D., 1983, ApJ, 268, 790
Kouveliotou, C., Dieters, S., Strohmayer, T., et al., 1998, Nature, 393, 235
Kouveliotou, C., Strohmayer, T., Hurley, K., et al., 1999, ApJ, 510, L115
Levine, A., Rappaport, S., Putney, A., et al., 1991, ApJ, 381, 101
Li, F., Rappaport, S. & Epstein, A., 1978, Nature, 271, 37
Lipunov, V. M., 1992, Astrophysics of Neutron Stars, Springer-Verlag
Lyne, A. G. & Graham-Smith, F., 1998, Pulsar Astronomy, Cambridge University Press, p. 94-96.
Lyne, A. G., Manchester, R. N., Lorimer, D. R., et al., 1998, MNRAS, 295, 743
Marsden, D., Lingenfelter, R., Rothschild, R. & Higdon, J., 1999, American Astronomical Society Meeting, 195, 26.05
Mavromatakis, F., 1993, A&A, 276, 353
Mereghetti, S., 1995, ApJ, 455, 598
Mereghetti, S. & Stella, L., 1995, ApJ, 442, L17
Mereghetti, C., 2001, astro-ph/0102017v1
Menou, K., Perna, R., & Hernquist, L. 2001, ApJ, in press (astro-ph/0102049)
Morini, M., Robba, N. R., Smith, A. & van der Klis, M., 1988, ApJ, 333, 777
Oosterbroek, T., Parmar, A. N., Mereghetti, S. & Israel, G. L., 1998, A&A, 334, 925
Pacini, F., 1967, Nature, 216, 567

Peng, Q., -H., Huang, K., -L. & Huang, J., -H., 1982, A&A, 107, 258
Robba, N. R., Cusumano, G., Orlandini, M., et al., 1992, ApJ, 401, 685
Robba, N. R., Burderi, L., Wynn, G. A., et al., 1996, ApJ, 472, 341
Rubin, B. C., Finger, M. H., Scott, D. M., Wilson, R. B., 1997, ApJ, 488, 413
Salpeter, E. E., 1964, ApJ, 140, 796
Schwartsman, V., 1970, Ast. Zh., 47, 824
Seward, F. D., Charles, P. A. & Smale, A. P., 1986, ApJ, 305, 814
Sonobe, T., Murakami, T., Kulkarni, S. R., Aoki, T. & Yoshida, A., 1994, ApJ, 436, L23
Sugizaki, M., Nagase, F., Torii, K., et al., 1997, PASJ, 49, L25
Tagieva, S. O. & Ankay, A., 2002, to be published in AATr
Tjemkes, S. A., van Paradijs, J. & Zuiderwijk, E. J., 1986, A&A, 154, 77
Tsunemi, H., Kitamoto, S. & Tamura, K., 1996, ApJ, 456, 316
Vasisht, G. & Gotthelf, E. V., 1997, ApJ, 486, L129
Vink, J., Bloemen, H., Kasstra, J. S. & Bleeker, J. A. M., 1998, A&A, 339, 201
Vrtilek, S. D., Boroson, B., Cheng, F. H., et al., 1997, ApJ, 490, 377
Weisskopf, M. C., Elsner, R. F., Darbro, W., et al., 1984, ApJ, 278, 711
White, N. E., Angelini, L., Ebisawa, K., Tanaka, Y. & Ghosh, P., 1996, ApJ, 463, L83
Woo, J. W., Clark, G. W., Levine, A. M., et al., 1996, ApJ, 467, 811
Yokogawa, J., Imanishi, K., Tsujimoto, M., et al., 2000, ApJS, 128, 491
Zeldovich Ya. B. & Guseinov, O. H., 1965, ZhETF Pis. Red., 1, 11
Zeldovich Ya. B. & Guseinov, O. H., 1966, ApJ, 144, 841

Table 1: The Data of AXPs/SGRs, and X-ray Pulsars in X-ray Binaries with Measured $\dot{\mathrm{P}}$ Values

Names	P_{orb} (d)	P (s)	$\dot{P}10^{-11}$ (s/s)	$L_x 10^{36}$ (erg/s)	$\lvert\dot{E}\rvert = 3.9410^{78}\frac{\lvert\dot{P}\rvert}{P^3}$ (erg/s)	$L_x/\lvert\dot{E}\rvert 10^3$	$Ref.$
H053109- 6609.2 T LMC	~ 700	13.68	3.7	2.4 $(0.1-2.4)$ 10 $(2-10)$	5.7	$5-20$	$[1,2,3]$
H0532- 664 LMC	1.41	13.5	6.1	400	10	400	$[4,5,15,16]$
L1627- 673 Q	0.029	7.67	17	2 $(2-10)$ 0.033	44	$0.5-0.75$	$[8,9,10]$
H1119- 603 Q	2.09	4.82	-3.8	44 $(2-10)$	140	3	$[6,7,20]$
H0115- 737 SMC	3.89	0.71	-1.6	111	17000	0.065	$[17,18,19]$
H0352 +309	580.7	836.8	420	0.006 $(0.1-2.4)$	0.0029	20	$[11,12,13,14]$
H1538- 522	3.73	529	390	2.9 $(1-15)$	0.01	2900	$[21,22,23,24]$
1E1841- 045 AXP		11.77	4.1	0.4 $(0.1-12)$	9.9	0.4	$[25,26]$
J170849- 4009 AXP		11	2.25	1 $(0.1-2.4)$	6.7	1.5	$[27,28]$
0142+614 AXP		8.69	~ 0.22	0.1 $(0.1-2.4)$	1.2	0.8	$[41,42,43]$
2259+587 AXP		6.98	0.06	0.2 $(0.5-4)$	0.69	3	$[29,30,31,32]$
1048.1- 5937 AXP		6.45	~ 2	$0.0063-0.3$ $(0.1-2.4)$	29	$0.002-0.1$	$[33,34,35,36]$
1806-20 SGR		7.47	8.3	1 $(0.5-10)$	78	0.13	$[37]$
1900+14 SGR		5.16	6	0.1 $(2-10)$	320	0.003	$[38,39,40]$

[1] Haberl et al. 1995; [2] Hanson et al. 1989; [3] Burderi et al. 1998; [4] Levine et al. 1991; [5] Woo et al. 1996; [6] Burderi et al. 2000; [7] Tsunemi et al. 1996; [8] Mereghetti & Stella 1995; [9] Chakrabarty et al. 1997; [10] Angelini et al. 1995; [11] Hutchings et al. 1974; [12] Mavromatakis 1993; [13] Robba et al. 1996; [14] Weisskopf 1984; [15] Li et al. 1978; [16] Vrtilek et al. 1997; [17] Tjemkes et al. 1986; [18] Yokogawa et al. 2000; [19] Bonnet-Bidaut & van der Klis 1981; [20] Kelley et al. 1983; [21] Clark 2000; [22] Clark et al. 1994; [23] Rubin et al. 1997; [24] Robba et al. 1992; [25] Vasisht & Gotthelf 1997; [26] Gotthelf et al. 1999; [27] Sugizaki et al. 1997; [28] Israel et al. 1999a; [29] Baykal & Swank 1996; [30] Fahlman & Gregory 1981; [31] Kaspi et al. 1999; [32] Morini et al. 1988; [33] Corbet & Mihara 1997; [34] Seward, et al. 1986; [35] Mereghetti, 1995; [36] Oosterbroek et al. 1998; [37] Kouveliotou et al. 1998; [38] Kouveliotou et al. 1999; [39] Sonobe et al. 1994; [40] Marsden et al. 1999; [41] Israel et al. 1999b; [42] White et al. 1996; [43] Israel et al. 1994.

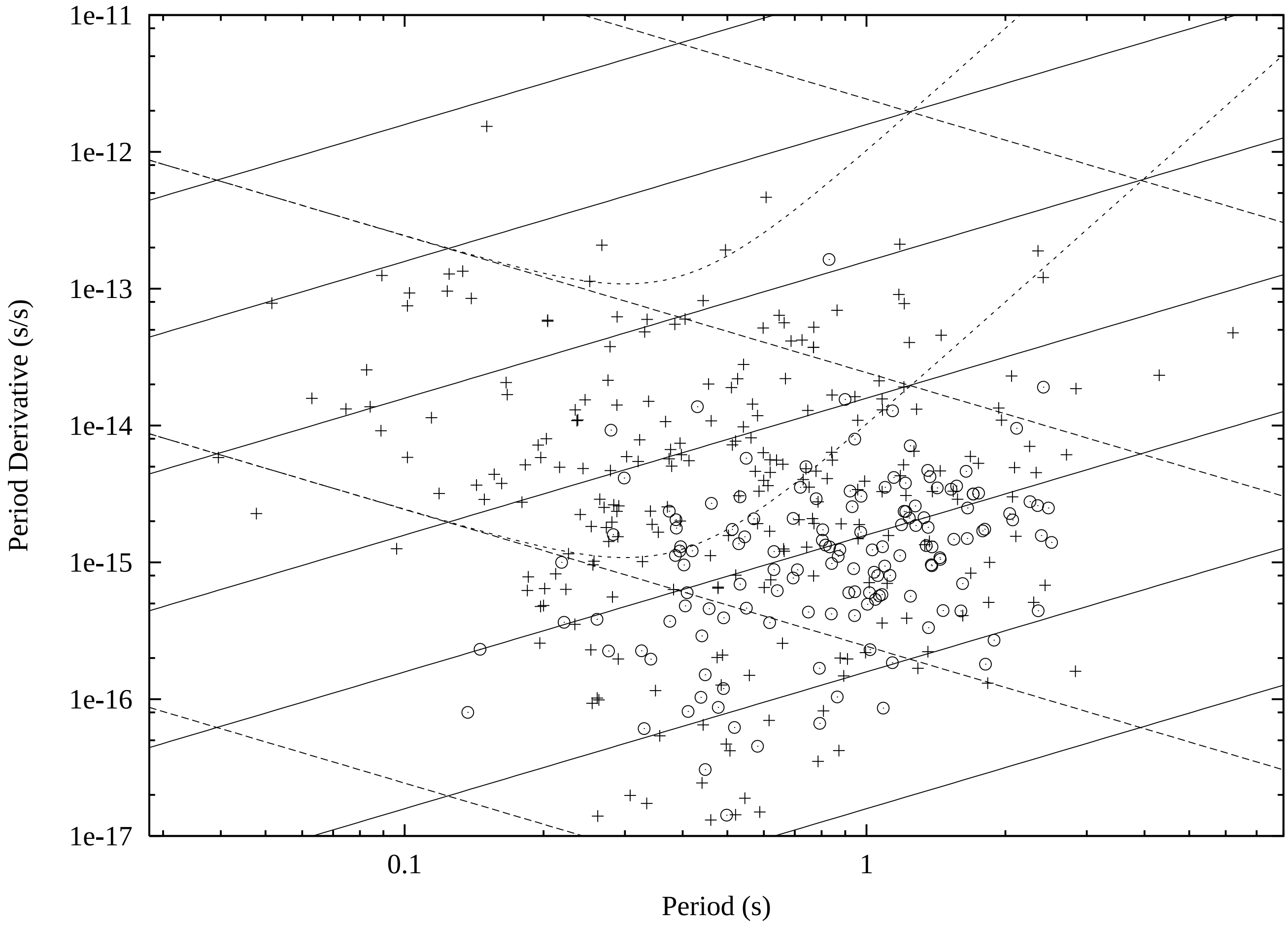

Figure 1. P-$\dot{\mathrm{P}}$ diagram for PSRs up to 4 kpc. Characteristic age lines (calculated from pure magnetic dipole radiation) are from 10^3 to 10^9 yrs. Constant magnetic dipole field lines range from 5×10^{10}-5×10^{13} gauss. The two curves, taken from Alpar et al. (2001), represent the evolution of pulsars due to dipole+propeller torques.